OHIO SHALE CONODONTS

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Although conodonts are numerous in the Ohio shale, they have received very little attention. To my knowledge, Cooper's paper (1931a), in which seven species are described from the top of the shale just northeast of Columbus, is the only publication on the subject. The present study encompasses a large variety of species and is the forerunner of a comprehensive study of the conodont fauna.

The material for this paper was collected from the lower portion of the Ohio shale where it is exposed along a few small tributary streams of the Olentangy River about two miles northwest of Worthington, in central Franklin County. Thirty-seven previously described species and eighteen genera are recognized. Twelve forms are unassigned because of doubtful relationships. Among these may be several new species and at least one new genus. It is hoped that these doubtful forms can be described when additional material is collected and studied.

The species described in this paper are listed as follows:

Ancyrognathus irregularis Branson and Mehl
Bryantodus commutatus Huddle
Bryantodus concavus Huddle
Bryantodus germanus Holmes
Bryantodus inequalis Holmes
Bryantodus nitidus Ulrich and Bassler
Bryantodus serrulus Huddle
Bryantodus subcarinatus Huddle
Bryantodus subequalis Cooper
Bryantodus subplanus Huddle
Euprioniodina prona Huddle
Hibbardella angulata (Hinde)
Hindeodella aculeata Huddle
Hindeodella alternata Ulrich and Bassler
Hindeodella germana Holmes
Hindeodella subtilis Ulrich and Bassler
Hindeodella sp. 1
Hindeodella sp. 2
Hindeodelloides bicristatus Huddle
Ligonodina sp. 1
Ligonodina sp. 2
Ligonodina sp. 3
Lonchodina multidens Hibbard
Lonchodina perarcuata Ulrich and Bassler
Lonchodina perlonga Ulrich and Bassler
Metaprioniodus biangulatus Huddle
Ozarkodina delicatula (Stauffer and Plummer)
Palmatodella delicatula Ulrich and Bassler
Palmatodella ? sp.
Palmatolepis glabra Ulrich and Bassler
Palmatolepis quadrantinodosa Branson and Mehl
Palmatolepis regularis Cooper
Palmatolepis subperlobata Branson and Mehl
Polygnathus nodocostata Branson and Mehl
Polygnathus pennatuloidea Holmes
Polygnathus sublatus Ulrich and Bassler
Polygnathus sp.
Prioniodina separans Holmes
Prioniodus alatoides Holmes
Prioniodus alatoideus Cooper
Prioniodus alatus Hinde
Prioniodus cultratus Ulrich and Bassler
Spathognathodus subrectus (Holmes)
Subbryantodus radians Branson and Mehl
Subbryantodus sp.
Synprioniodina sp.
Distacods, 3 sp.
Dermal plates, 2 sp.

No additional evidence is furnished by the present conodont collection to aid in the solution of the general problem of the stratigraphic position of the Ohio shale. It is expected, however, that future studies will reveal data of value in determining the age relationships of the formation.

The conodonts occur most commonly in very thin bone beds in the shale, with only occasional specimens scattered between the beds. Some of these bone beds are located at the contacts between the black shale and interbedded layers of gray shale. Others may be found as very thin layers along bedding planes in black shale of uniform lithology. In most places the conodonts are rather evenly distributed laterally, but in one place at least they are concentrated in small discontinuous patches which consist largely of conodont fragments. This latter occurrence suggests that they were brought together by small eddies or currents in

the water and that they were moved about considerably as they were being deposited, thus resulting in their fragmental condition.

The state of preservation of the conodonts at the different exposures varies in a marked degree. In some places the fossils are largely broken, but the fragments are excellently preserved. In other layers the conodonts have been dissolved away by the sulfuric acid produced by the weathering of pyrite and marcasite in the shale outcrops and have left clearly defined impressions or molds which are usually sufficiently complete to permit identification.

The conodonts are quite variable in color, some being white, some amber-colored and transluscent, and others are colorless and so transparent that the shale on which they lie may be seen through them. Many of the specimens examined have a high luster. In general, the fossils of any one bed are similar in color regardless of the species.

Associated with the conodonts are small dermal plates, minute black spines, small carbonaceous fragments of wood, and a great abundance of plant spore cases which are in some instances so numerous that the surfaces of the shale are almost completely covered with them. In two of the bone beds which were studied a fine network of minute cylindrical tubes was observed. These are filled mostly with pyrite and marcasite crystals, but in places they are hollow. Their identity is unknown.

For the most part the conodonts described in this paper had to be studied in place on the slightly weathered surfaces of the thin layers of shale, because when the rock was broken down the conodonts fell apart along minute fractures. Some fossil material was separated successfully from the shale by boiling in a solution of sodium hydroxide, and the conodonts were recovered by sifting and by using liquid separates. Material thus separated from the shale consisted largely of fragments, but some identifiable specimens of the simple cone type as well as many minute specimens of the platform type were recovered. These will be studied at a later time.

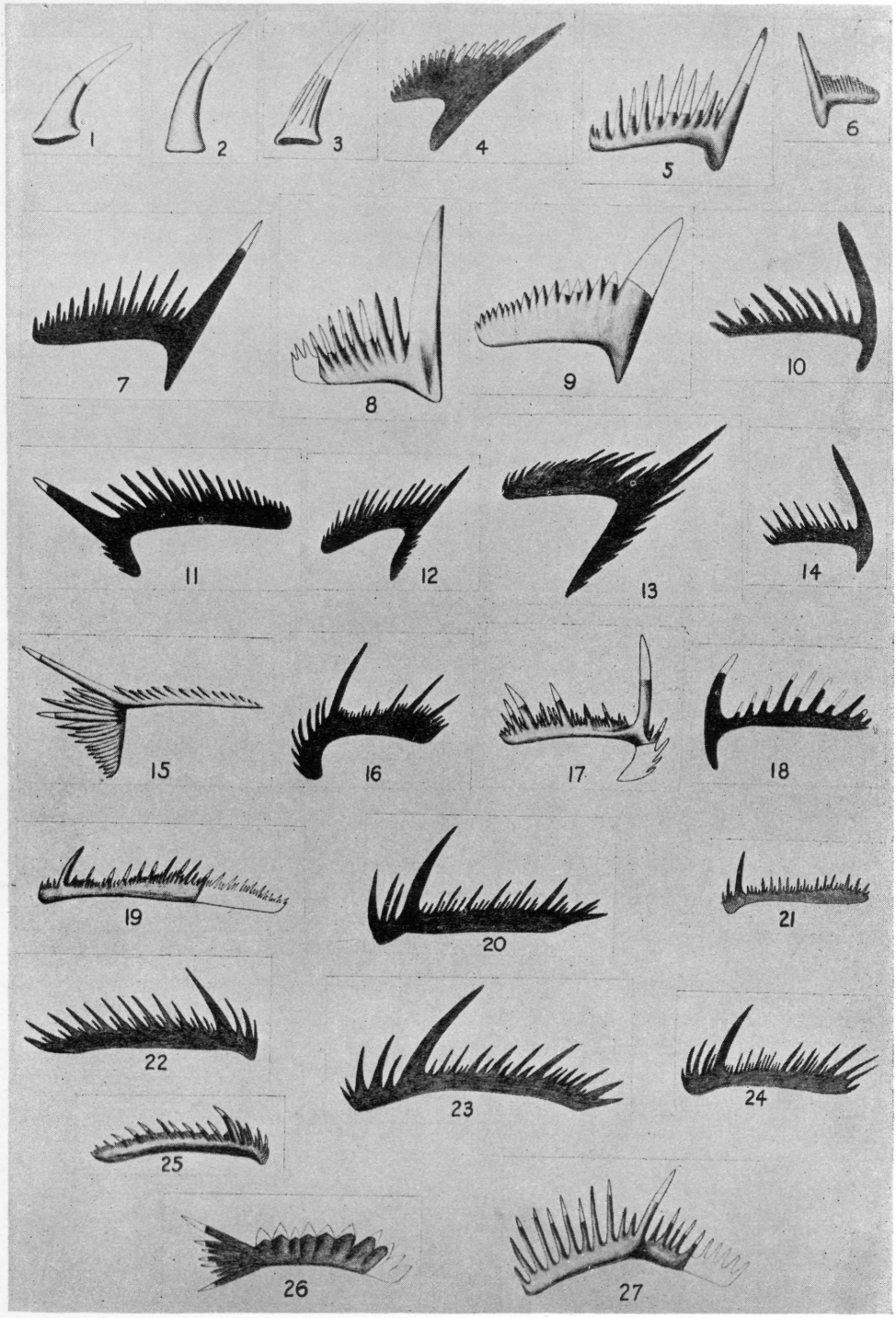
The total number of fossils preserved sufficiently well for study was about 450. This is a rather small number considering that at least thirty-seven species are represented. Branson and Mehl have also noted a proportionately large number of species relative to the specimens examined in their collections from the Harding sandstone of Colorado (1933a, p. 22), and from the Grassy Creek shale of Missouri (1933b, p. 183).

Acknowledgment is made of the assistance of Dr. Grace A. Stewart of the Department of Geology, Ohio State University, who directed the paleontological research.

EXPLANATION OF PLATE I

All specimens are from the lower portion of the Ohio shale, upper Devonian, central Ohio. Magnification as noted.

Figs. 1–3, Distacodidae. Figured specimens: ×50 (p. 23). **4, 6,** *Prioniodus alatoideus* Cooper. Hypotypes: 4, an impression, ×30; 6, × 25 (p. 23). **5, 7,** *Prioniodus alatoides* Holmes. Hypotypes: 7, an impression. ×25 (p. 23). **8,** *Prioniodus cultratus* Ulrich and Bassler. Hypotype: ×25 (p. 23). **9,** *Prioniodus alatus* Hinde. Hypotype: ×20 (p. 23). **10,** *Ligonodina* sp. 1. Figured specimen: an impression. ×12 (p. 23). **11, 12,** *Euprioniodina prona* Huddle. Hypotypes: impressions. ×25 (p. 23). **13,** *Synprioniodina* sp. Figured specimen: an impression. ×20 (p. 23). **14,** *Ligonodina* sp. 2. Figured specimen: an impression. ×10 (p. 23). **15,** *Palmatodella delicatula* Ulrich and Bassler. Hypotype: ×20 (p. 23). **16, 17,** *Hindeodelloides bicristatus* Huddle. Hypotypes: 16, an impression, ×20; 17, ×25 (p. 23). **18,** *Ligonodina* sp. 3. Figured specimen: an impression. ×12 (p. 23). **19, 21,** *Hindeodella aculeata* Huddle. Hypotypes: ×12 (p. 23). **20,** *Hindeodella* sp. 2. Figured specimen: an impression. ×25 (p. 23). **22,** *Hindeodella germana* Holmes. Hypotype: an impression. ×15 (p. 23). **23,** *Hindeodella alternata* Ulrich and Bassler. Hypotype: an impression. ×24 (p. 23). **24,** *Hindeodella* sp. 1. Figured specimen: an impression. ×14 (p. 23). **25,** *Hindeodella subtilis* Ulrich and Bassler. Hypotype: ×20 (p. 23). **26,** *Palmatodella ?* sp. Figured specimen: an impression. ×20 (p. 23). **27,** *Prioniodina separans* Holmes. Hypotype: ×12 (p. 23).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Systematic Descriptions

Family **Distacodidae** (Ulrich and Bassler, 1926)

The specimens illustrated on Plate I, figures 1–3, represent a small group of distacods recovered from conodont bone bed material by boiling, washing, and screening through the 100-mesh sieve. They are somewhat smaller than many of the distacods described in the literature, but they compare favorably in size with several specimens from Pander's conodont material which was available for comparison. An opaque white appearance is developed more or less completely in these tiny cones, a characteristic which they share with the blade or platform type conodonts recovered with them in the screenings. This opacity conceals the growth axes. The upper parts of the cones have been broken away, but otherwise the luster, striae, and thin edges of the basal cavities are well preserved. Pending the collection and study of additional material no specific nor generic assignments can be made with any assurance at this time.

The illustration on Plate I, figure 1, represents a minute, simple cone having a base which is extended and flared both anteriorly and posteriorly. The basal cavity is moderately large. The cusp is thin, long, curved moderately, slightly compressed laterally, smooth, with a faint keel developed on the anterior edge. (Figured specimen, Ohio State University Geological Museum, no. 18367c.)

Figure 2 on Plate I illustrates a simple cone with a small oval base which is very slightly expanded and has a rather shallow cavity. The cusp is oval in cross-section, smooth, and slightly curved, forming a high angle with the plane of the base. (Figured specimen, Ohio State University Geological Museum, no. 18367a.)

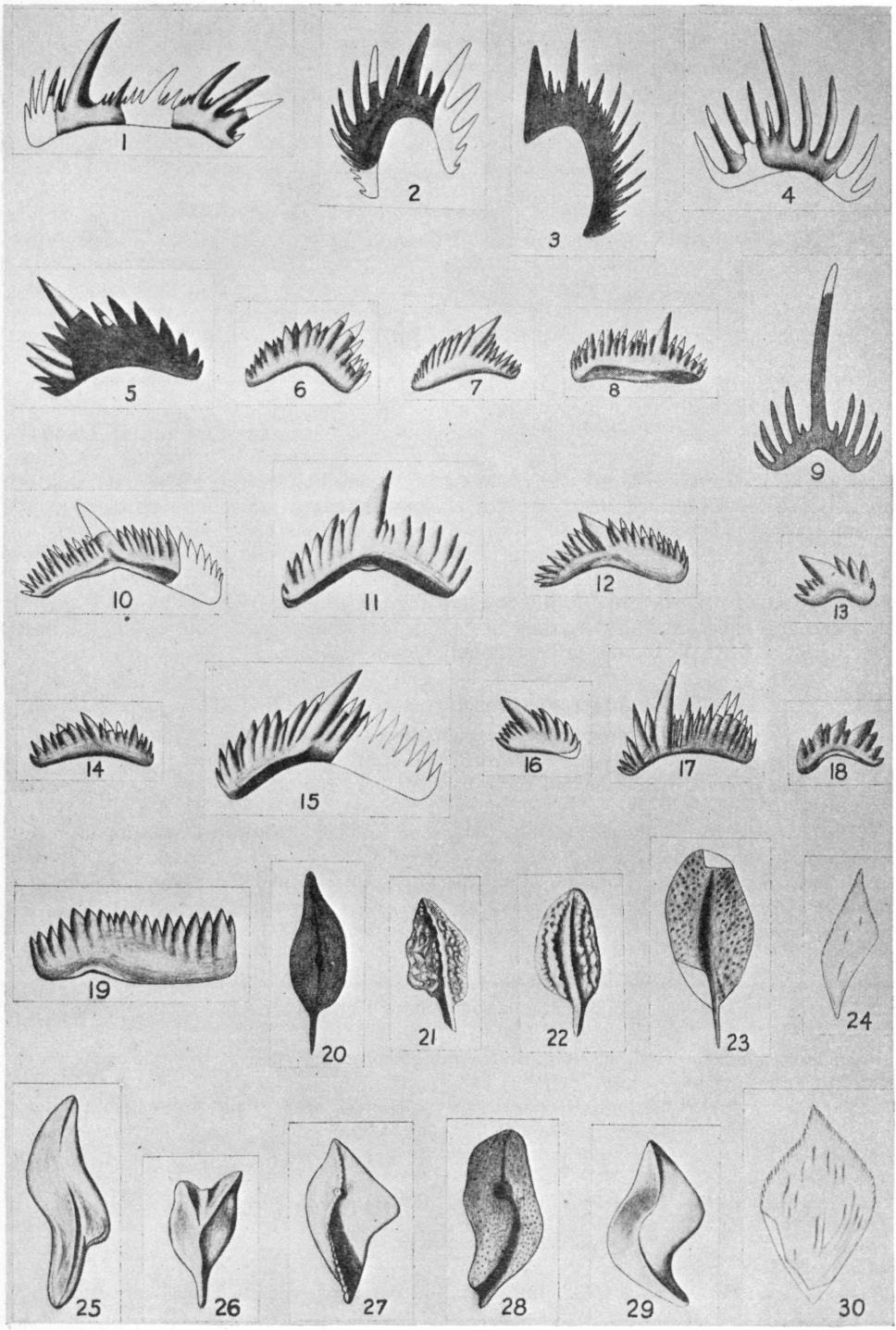
The specimen illustrated on Plate I, figure 3, is a simple cusp with the base slightly but sharply expanded with a broad, shallow basal cavity, and a thin-lipped basal edge. The cusp is laterally compressed, marked with longitudinal striae and a small sharp keel on the anterior edge. It is slightly inclined and curved and thus forms a high angle with the plane of the base. (Figured specimen, Ohio State University Geological Museum, no. 18367b.)

How should the presence of these simple cones in Devonian strata be interpreted? Branson and Mehl (1933b, p. 210) on the basis of their extensive conodont collections, believe that the distacods died out in the Silurian, and Ellison in his recent table showing the stratigraphic ranges of conodonts (1946, p. 94, fig. 1)

EXPLANATION OF PLATE II

All specimens are from the lower portion of the Ohio shale, upper Devonian, central Ohio. Magnification as noted.

Fig. 1, *Metaprioniodus biangulatus* Huddle. Hypotype. ×30 (p. 25). **2,** *Lonchodina perarcuata* Ulrich and Bassler. Hypotype: an impression. ×15 (p. 25). **3,** *Lonchodina multidens* Hibbard. Hypotype: an impression. ×20 (p. 25). **4,** *Lonchodina perlonga* Ulrich and Bassler. Hypotype. ×25 (p. 25). **5,** *Bryantodus concavus* Huddle. Hypotype: an impression. ×30 (p. 25). **6,** *Bryanthodus commutatus* Huddle. Hypotype: ×24 (p. 25). **7, 12,** *Ozarkodina delicatula* (Stauffer and Plummer). Hypotypes: ×30 (p. 25). **8,** *Bryantodus germanus* Holmes. Hypotype: ×24 (p. 25). **9,** *Hibbardella angulata* (Hinde). Hypotype: an impression. ×12 (p. 25). **10,** *Bryantodus inequalis* Holmes. Hypotype: ×18 (p. 25). **11,** *Bryantodus nitidus* Ulrich and Bassler. Hypotype: a restoration based on mold. ×20 (p. 25). **13,** *Subbryantodus radians* Branson and Mehl. Hypotype: ×30 (p. 25). **14,** *Bryantodus serrulus* Huddle. Hypotype: ×25 (p. 25). **15,** *Bryantodus subcarinatus* Huddle. Hypotype: ×20 (p. 25). **16,** *Bryantodus subequalis* Cooper. Hypotype: ×30 (p. 25). **17,** *Bryantodus subplanus* Huddle. Hypotype: ×25 (p. 25). **18,** *Subbryantodus* sp. Figured specimen: ×24 (p. 25). **19,** *Spathognathodus subrectus* (Holmes). Hypotype: ×20 (p. 25). **20,** *Polygnathus* sp. Figured specimen: ×35 (p. 25). **21,** *Polygnathus pennatuloides* Holmes. Hypotype: ×20 (p. 25). **22,** *Polygnathus nodocostata* Branson and Mehl. Hypotype: ×12 (p. 25). **23,** *Polygnathus sublatus* Ulrich and Bassler. Hypotype: ×15 (p. 25). **24, 30,** Dermal plates. Figured specimens: 24, ×12; 30, ×8 (p. 25). **25,** *Palmatolepis glabra* Ulrich and Bassler. Hypotype: ×20 (p. 25). **26,** *Ancyrognathus irregularis* Branson and Mehl. Hypotype: ×12 (p. 25). **27,** *Palmatolepis subperlobata* Branson and Mehl. Hypotype: ×20 (p. 25). **28,** *Palmatolepis quadrantinodosa* Branson and Mehl. Hypotype: ×20 (p. 25). **29,** *Palmatolepis regularis* Cooper. Hypotype: ×12 (p. 25).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emphasizes their Silurian extinction. These authors state that the numerous references to post-Silurian distacods in the literature are the result of failure to recognize that the cones are the broken-off cusps of Devonian or younger blade and bar types of conodonts or are foreign elements in stratigraphic admixtures. They have discussed many of these mixed faunas in considerable detail (Branson and Mehl, 1940; Ellison, 1946, pp. 100–102).

There is no evidence to suggest that the Ohio shale distacods are an admixture from earlier stratigraphic horizons. The specimens were collected from strata well above the basal contact of the formation, and there is no indication of any intraformational breaks. The distacods have essentially the same color and luster as the typical Devonian genera *Palmatolepis* and *Hindeodella*. The presence of distinct basal cavities and smooth, perfectly defined, unbroken basal margins unquestionably relates them to the family Distacodidae and eliminates *Lonchodina* and *Euprioniodina* assignments such as Branson and Mehl have made for some of their Grassy Creek cone-shaped conodonts (1933b, pp. 210, 211, pl. 15, figs. 15, 21).

The problem resolves itself into a study of three alternatives: 1, the recognition of a stratigraphic admixture; 2, an extension of the range of the distacods beyond the Silurian; 3, separation of these Devonian forms from the family Distacodidae on some basis, however slight, frankly for utilitarian purposes. This last alternative is comparable to the problem of variability of species as commented upon by P. E. Raymond (1941, p. 99), who points out that specimens from zones of different ages are split into different species on the basis of minor characteristics which are considered merely as variations for specimens in the same zone, and notes that this course ". . . by some . . . is carried to such an extreme that the locality seems to be the chief guide to identification."

Further collections and studies are considered necessary before any definite conclusion on this problem can be reached.

Genus **Ancyrognathus** Branson and Mehl, 1933

Ancyrognathus irregularis Branson and Mehl

Plate II, figure 26

Ancyrognathus irregularis Branson and Mehl, 1933, Missouri Univ. Studies, vol. 8, no. 3, p. 242, pl. 19, figs. 1, 2, 4, 10, 16.

Plate broad, irregularly lobate anteriorly, oral surface ornamented with small nodes irregularly arranged, aboral surface with fine concentric lines and a bifurcating keel; carina prominent, composed of fused nodes, bifurcating near center of plate, the branches extending to the ends of the lobes; blade short, heavy, denticulate.

Hypotype, Ohio State University Geological Museum, no. 18417.

Genus **Bryantodus** Ulrich and Bassler, 1926

Bryantodus commutatus Huddle

Plate II, figure 6

Bryantodus commutatus Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 70, pl. 2, figs. 13, 14.

Bar thick, rounded, moderately arched, curved laterally, with a faint keel extending along the entire length of the bar; cusp rather small, in some specimens indistinguishable from adjacent denticle; denticles fused except near tips, somewhat irregular in size, diminishing in length toward the ends of the bar.

Hypotype, Ohio State University Geological Museum, no. 18396.

Bryantodus concavus Huddle

Plate II, figure 5

Bryantodus concavus Huddle, 1934, Bull. Am. Paleontology, vol. 21, No. 72, p. 71, pl. 2, figs. 15–17.

Bar broad, smooth, laterally compressed, strongly arched; cusp long, thick at base, acutely pointed; denticles short, nearly parallel, confluent except at tips, six or eight on each side of cusp.

Hypotype, Ohio State University Geological Museum, no. 18397.

Bryantodus germanus Holmes

Plate II, figure 8

Bryantodus germanus Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 28, pl. 10, fig. 5.

Bar high, thin, slightly curved laterally but not arched, with a lateral ridge extending along its whole length, aboral edge sharp; cusp short, thick, rounded, inclined slightly; denticles short, close-set but not confluent, twelve anterior to cusp nearly vertical, six posterior to cusp slightly inclined.

Hypotype, Ohio State University Geological Museum, no. 18399.

Bryantodus inequalis Holmes

Plate II, figure 10

Bryantodus inequalis Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 27, pl. 10, figs. 1, 2. (Not *B. inequalis* Branson and Mehl, 1933, Missouri Univ. Studies, vol. 8, p. 219, pl. 16, figs. 17, 18.)

Bar long, moderately arched, anterior half with prominent median ridge, posterior part thin, slightly curved laterally, aboral edge sharp; cusp short, broad, slightly recurved, inclined; denticles short, sharp-edged, close-set but not fused, ten to fourteen on each side of cusp, the anterior ones being larger and more inclined than those on posterior part of bar.

Remarks.—As noted in the synonymy, the specific name *inequalis* used by Branson and Mehl, was preoccupied by Holmes and a substitute should be proposed. (See Youngquist, 1945, p. 358.)

Hypotype, Ohio State University Geological Museum, no. 18400.

Bryantodus nitidus Ulrich and Bassler

Plate II, figure 11

Bryantodus nitidus Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 24, pl. 4, figs. 12–14.

Bar heavy, moderately arched, anterior part with prominent median ridge which extends along posterior part as a lateral expansion at base of denticles, aboral edge sharp with a slight expansion beneath cusp; cusp subcentral, rather short, thick, moderately inclined; long, slightly inclined denticles anterior to cusp; rather short, massive, vertical denticles posterior to cusp; all close-set but not confluent.

Hypotype, Ohio State University Geological Museum, no. 18401.

Bryantodus serrulus Huddle

Plate II, figure 14

Bryantodus serrula Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 71, pl. 2, figs. 18–20.

Bar moderately high and thick, slightly arched; cusp inclined, small, only slightly longer and thicker than the denticles; denticles numerous, small, inclined, close-set but not confluent, inserted, a few suppressed denticles present between bases of the developed denticles.

The aboral edges of the specimens observed are imperfectly preserved and therefore do not show characteristics of apical pit or groove.

Hypotype, Ohio State University Geological Museum, no. 18404.

Bryantodus subcarinatus Huddle

Plate II, figure 15

Bryantodus subcarinatus Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 74, pl. 4, figs. 7, 8.

Bar long, thick, moderately arched, posterior part rounded, anterior part with prominent lateral ridge; cusp long, rather thin, inclined; denticles long, thin, straight, appressed but not confluent, seven to ten on each side of cusp, anterior ones vertical, posterior ones inclined.

Hypotype, Ohio State University Geological Museum, no. 18405.

Bryantodus subequalis Cooper

Plate II, figure 16

Bryantodus subequalis Cooper, 1931, Jour. Paleontology, vol. 5, p. 234, pl. 28, fig. 11.

Tooth very small, bar short, rather strongly arched; cusp proportionately large, inclined; denticles small, closely appressed and confluent, deeply inserted, four to six on each side of cusp, those anterior to cusp slightly curved and larger than the posterior denticles.

Hypotype, Ohio State University Geological Museum, no. 18406.

Bryantodus subplanus Huddle

Plate II, figure 17

Bryantodus subplanus Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 73, pl. 4, figs. 5, 6.

Bar thin, slightly arched; cusp long, slightly curved and inclined; denticles long, appressed, deeply inserted, minute suppressed denticles between large ones in central part of bar; anterior denticles large, slightly curved, five or six in number, decreasing in length anteriorly; posterior denticles near cusp thin and short, those near end of bar large.

Hypotype, Ohio State University Geological Museum, no. 18407.

Genus **Euprioniodina** Ulrich and Bassler, 1926

Euprioniodina prona Huddle

Plate I, figures 11, 12

Euprioniodina prona Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 52, pl. 6, fig. 19; pl. 11, fig. 8.

Bar long, somewhat compressed, slightly arched; cusp short, round, thick at base but tapering to a sharp point, inclined strongly forward; anticusp wide, compressed, extending in line with cusp, bearing fine denticles which are close-set and inclined sharply upward; denticles on bar numerous, long, thin, slightly curved and inclined forward, minute denticles set between most of the larger ones.

The species is represented in this collection by clear impressions which closely resemble *Synprioniodina alternata* Ulrich and Bassler (1926, p. 42, text fig. 22 on p. 16). The distinction is made on the basis of the discrete bar denticles which are absent in the genus *Synprioniodina*, and also on the basis of the cusp and anticusp extending in a line as in *Euprioniodina prona*.

Hypotypes, Ohio State University Geological Museum, nos. 18374, 18375.

Genus **Hibbardella** Ulrich and Bassler, 1926

Hibbardella angulata (Hinde)

Plate II, figure 9

Hibbardella angulata (Hinde), 1926, Ulrich and Bassler, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 37, pl. 3, figs. 1–4.

Bar highly arched, limbs moderately heavy, rounded, nearly straight; cusp long, thick, rounded, very slightly curved; denticles rather short, rounded, well separated, slightly curved toward the cusp, four or five on each side of the bar.

Hypotype, Ohio State University Geological Museum, no. 18409.

Genus **Hindeodella** Ulrich and Bassler, 1926

Hindeodella aculeata Huddle

Plate I, figures 19, 21

Hindeodella aculeata Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 40, pl. 4, figs. 19–21; pl. 5, figs. 2, 3.

Bar straight or slightly curved, long, thin, rounded, oral shoulder distinct, anterior portion of bar sharply curved laterally and slightly expanded downward; cusp rounded, curved and inclined posteriorly; denticles inserted, straight, rounded, inclined posteriorly, three or four small denticles between the large ones.

The oral shoulder distinguishes this species from *Hindeodella subtilis* Ulrich and Bassler (1926, p. 39, pl. 8, figs. 17–19).

Hypotypes, Ohio State University Geological Museum, nos. 18383, 18384.

Hindeodella alternata Ulrich and Bassler

Plate I, figure 23

Hindeodella alternata Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 40, pl. 1, figs. 14, 15.

Bar straight or slightly arched, moderately thick, laterally compressed, anterior portion depressed and curved laterally; cusp long, thick, rounded, curved and inclined backward; several prominent posterior denticles progressively larger and more inclined posteriorly with one to three small denticles set between the larger ones, terminal denticles spine-like; anterior denticles large, slightly curved.

Although the species is represented in the material studied only by impressions, the large cusp and prominent posterior denticles with small denticles set between them are sufficient to identify the species. The form is distinguished from *H. germana* Holmes (1928, p. 25, pl. 9, fig. 9) by the progressive increase in size of the denticles posteriorly. The Ohio shale specimens, like the one from Montana figured by Cooper and Sloss (1943, pl. 29, fig. 18), lack the prominent terminal spine as developed in the cotypes.

Hypotype, Ohio State University Geological Museum, no. 18387.

Hindeodella germana Holmes

Plate I, figure 22

Hindeodella germana Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 25, pl. 9, fig. 9.

Bar rather short, thick, posterior part straight except for a slight downward deflection at the posterior end where it terminates in a spine-like point, anterior part bent sharply laterally and slightly curved downward; cusp long, slender; denticles ten to fifteen in number, less than half as long as cusp, straight, inclined posteriorly, one or sometimes two minute denticles set between large ones.

Hypotype, Ohio State University Geological Museum, no. 18386.

Hindeodella subtilis Ulrich and Bassler

Plate I, figure 25

Hindeodella subtilis Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 39, pl. 8, figs. 17–19.

Bar long, rather high and thick; posterior part straight or slightly arched, anterior part deflected downward slightly and curved sharply laterally; cusp long, nearly straight, inclined posteriorly; denticles numerous, small, alternating with three or four minute ones set between the longer ones except for those in front of the cusp which are irregularly arranged.

Hypotype, Ohio State University Geological Museum, no. 18388.

Hindeodella sp. 1

Plate I, figure 24

Bar probably thin, posterior part horizontally straight but slightly bowed laterally, anterior part deflected sharply downward and curved laterally, bearing four to six long denticles with several minute ones in between; cusp long, rounded, slightly curved posteriorly; denticles posterior to the cusp numerous, irregular in size and amount of inclination, generally progressively increasing in size and degree of inclination posteriorly, with fine denticles set between most of the large ones.

This form resembles *Hindeodella deflecta* Hibbard (1927, p. 207, fig. 4c), but the denticles are finer and more numerous than those of *H. deflecta*.

Figured specimen, Ohio State University Geological Museum, no. 18389.

Hindeodella sp. 2

Plate I, figure 20

Bar short, high, compressed, anterior part deflected slightly downward and curved laterally,

posterior part straight, terminating in two short spine-like denticles; cusp prominent, slightly curved and inclined backward; anterior denticles large and slightly curved, posterior denticles rather small with two or three minute denticles set between somewhat larger ones.

This species is represented by two well defined impressions. Its characteristics suggest a new species, but a study of more material is necessary before positive relationships can be determined.

Figured specimen, Ohio State University Geological Museum, no. 18385.

Genus **Hindeodelloides** Huddle, 1934

This genus was established to include forms which differ from *Hindeodella* in the presence of a denticulate anticusp as developed in the genoholotype *Hindeodelloides bicristatus*. Whether this anterior downward projection is an anticusp or merely an excessive bending of the bar is a matter of question which throws doubt on the justifiability of retaining the genus. Ellison (1946, p. 108) suggests the need of additional research before a conclusion can be reached and states that the genus "probably belongs to *Hindeodella* Ulrich and Bassler."

The few specimens observed from the Ohio shale which closely resemble *Hindeodelloides bicristatus* Huddle show an anterior downward deflection and recurving of the bar rather than a development of an anticusp. The evidence is not conclusive, however, and until better material can be studied, it seems best to assign these to the genus *Hindeodelloides*.

Hindeodelloides bicristatus Huddle

Plate I, figures 16, 17

Hindeodelloides bicristatus Huddle, 1934, Bull. Am. Paleontology, p. 48, pl. 7, figs. 2, 3; pl. 12, fig. 6.

Bar short, flattened, rather high, slightly curved, somewhat larger posteriorly than anteriorly; cusp prominent, long, slender, rounded, slightly curved and inclined posteriorly; denticles back of cusp close-set or appressed, straight and inclined posteriorly, minute denticles in between large ones; two or three prominent denticles on posterior part of bar, terminal denticles small; anterior downward projection (anticusp?) large, wide, and slightly recurved, bearing four or five large, up-curved denticles.

The specimens exhibit considerable variation in the length and thickness of the bar, and in the size and inclination of the cusp, but there is prominent similarity with respect to the large, recurved anterior downward projection and the prominent denticles on the posterior part of the bar. The species closely resembles *Hindeodella pumilla* Cooper (1931b, p. 236, pl. 28, fig. 18), but it lacks the long, slightly curved terminal denticle characteristic of that species.

Hypotypes, Ohio State University Geological Museum, nos. 18381, 18382.

Genus **Ligonodina** Ulrich and Bassler, 1926

The fundamental characteristics of the genus *Ligonodina* extend in three dimensions; therefore the features in the two-dimensional laminae surfaces are usually so incomplete that positive specific assignments cannot be made. The impressions described and figured in this paper are the most complete representatives of the dozen or so specimens studied.

Ligonodina sp. 1

Plate I, figure 10

Bar thin, moderately long, slightly curved; cusp long, laterally compressed, slightly curved backward; anticusp short with deep pits in the impression representing four or five denticles which extended from the anticusp at right angles to the plane of the bar and anticusp; bar denticles long, rounded, widely spaced, curved posteriorly, eight to ten in number, with minute denticles set singly between the larger ones on the posterior part of the bar. This form closely resembles *Ligonodina bicincta* Huddle (1934, p. 62, pl. 12, fig. 15).

Figured specimen, Ohio State University Geological Museum, no. 18378.

Ligonodina sp. 2

Plate I, figure 14

Bar short, straight, moderately thick; cusp long, rounded, slightly curved and inclined posteriorly; anticusp rather short, evidence of denticles on anticusp lacking; eight moderately long denticles on the bar with minute denticles set singly between the large ones. The impression shows a close similarity to *Ligonodina gouldi* Cooper (1935, p. 313, pl. 27, fig. 8).

Figured specimen, Ohio State University Geological Museum, no. 18380.

Ligonodina sp. 3

Plate I, figure 18

Bar long, thick, rounded; cusp long, rather thick, rounded, slightly curved posteriorly; anticusp not perfectly represented; bar denticles eight to ten in number, long, rounded, anterior ones apparently rather short, all curved and inclined posteriorly. The impression shows a general resemblance to *Ligonodina falciformis* Ulrich and Bassler (1926, p. 14, pl. 2, figs. 11–13).

Figured specimen, Ohio State University Geological Museum, no. 18379.

Genus **Lonchodina** Ulrich and Bassler, 1926

Lonchodina multidens Hibbard

Plate II, figure 3

Lonchodina multidens Hibbard, 1927, Am. Jour. Sci., 5th ser., vol. 13, p. 203, fig. 3i.

Bar thick, strongly arched, asymmetrical, anterior portion considerably longer than posterior part; cusp short, wide at base, situated near the apex of the arch; denticles curved upward, one or two minute ones set between most of the long ones; one posterior denticle nearly as long as cusp and somewhat more massive.

Hypotype, Ohio State University Geological Museum, no. 18393.

Lonchodina perarcuata Ulrich and Bassler

Plate II, figure 2

Lonchodina perarcuata Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 33, pl. 5, fig. 19.

Bar strongly arched, rather wide, with a faint lateral ridge; cusp large, rounded, slightly curved, situated at the apex of the arch; denticles quite short, round, anterior ones strongly curved upward, posterior ones almost straight, two of which are nearly equal in size to the cusp.

Hypotype, Ohio State University Geological Museum, no. 18394.

Lonchodina perlonga Ulrich and Bassler

Plate II, figure 4

Lonchodina perlonga Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 32, pl. 5, figs. 6, 7.

Bar slender, rounded, moderately arched; cusp long, slender, slightly curved; denticles widely separated, long, slender, similar to cusp, four to six on each side of cusp, those anterior to cusp curved, the others straight.

Hypotype, Ohio State University Geological Museum, no. 18395.

Genus **Metaprioniodus** Huddle, 1934

The genus *Metaprioniodus* was established to include forms similar to *Hindeodella* but distinguished by a posterior downward projection. Whether this characteristic is of generic or specific importance is questioned by Ellison (1946, p. 109) who recommends further research and suggests that *Metaprioniodus* probably belongs to *Hindeodella*. Pending further study it seems best to retain the genus *Metaprioniodus* for the two specimens collected from the Ohio shale which resemble very closely Huddle's genoholotype *Metaprioniodus biangulatus*.

Metaprioniodus biangulatus Huddle

Plate II, figure 1

Metaprioniodus biangulatus Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 57, pl. 11, figs. 12, 13.

Bar short, heavy, deflected downward in posterior portion, anterior part deflected downward and curved laterally; cusp large, rounded, curved and inclined posteriorly; several long thin denticles anterior to cusp, back of cusp a number of long and slender denticles alternate with one or two minute ones; three large posterior denticles are sharply inclined backward.

The distinct oral shoulder characteristic of the genoholotype is not developed on the specimens under discussion.

Hypotype, Ohio State University Geological Museum, no. 18391.

Genus **Ozarkodina** Branson and Mehl, 1933

Ozarkodina delicatula (Stauffer and Plummer)

Plate II, figures 7, 12

Ozarkodina delicatula (Stauffer and Plummer) Ellison, 1941, Jour. Paleontology, vol. 15, p. 120, pl. 20, figs. 40–42, 47.

Blade thin, slightly arched, with a slightly flaring lip along aboral edge in some specimens; cusp short but very wide, suppressing adjacent denticles; denticles deeply inserted, appressed, confluent nearly to tips, decreasing in size quite regularly toward ends of blade, nearly vertical at anterior end of blade but progressively more inclined posteriorly.

Hypotypes, Ohio State University Geological Museum, nos. 18398, 18402.

Genus **Palmatodella** Ulrich and Bassler, 1926

Palmatodella delicatula Ulrich and Bassler

Plate I, figure 15

Palmatodella delicatula Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 41, pl. 10, fig. 5, text fig. 10 on p. 16.

Bar bent anterio-centrally forming a right angle, each limb thin and straight; main denticle or cusp at bend in bar extending nearly in line with posterior limb of bar, posterior denticles small, inserted, closely appressed, strongly inclined forward; anterior denticles long, inserted, closely appressed with a few diminutive suppressed denticles, all at right angles to bar and tapering in length, forming the characteristic palmate structure.

Hypotype, Ohio State University Geological Museum, no. 18377.

Palmatodella ? sp.

Plate I, figure 26

Bar long, straight or slightly arched, probably thin; cusp long, slender, inclined strongly forward, not distinct from denticles below it in some specimens; bar denticles eight or ten in number, vertical, closely appressed, very wide and short, probably bluntly pointed; denticles below cusp long, slender, closely set, extending forward in palmate arrangement usually aligned in the vertical plane with the bar and its denticles.

This species is represented by six clearly defined impressions of such similarity that there is reasonable assurance that the essential characteristics have been preserved. It is similar in its general aspect to *Palmatodella delicatula* Ulrich and Bassler (1926, p. 41, text fig. 20, p. 16), but differs in having very broad, short, vertical denticles on the bar, and in the extension of the palmate denticles from the anterior end of the bar rather than from a downward deflection. The form certainly represents a new species and probably a new genus, but definite relationships cannot be established until better material is collected and studied.

Figured specimen, Ohio State University Geological Museum, no. 18390.

Genus **Palmatolepis** Ulrich and Bassler, 1926

Palmatolepis glabra Ulrich and Bassler

Plate II, figure 25

Palmatolepis glabra Ulrich and Bassler, 1933, Branson and Mehl, Missouri Univ. Studies, vol. 8, no. 3, p. 233, pl. 18, figs. 9, 22, 26.

Plate long and narrow, curved sigmoidally, outline regular except for an abrupt truncation of one side of plate near posterior end, aboral surface marked with fine concentric lines and a thin median keel, oral surface finely pustulose; carina consisting of ten or twelve nodes anterior to the azygous node, and a rather high, thin, node-crested blade increasing in height posteriorly.

Hypotype, Ohio State University Geological Museum, no. 18416.

Palmatolepis quadrantinodosa Branson and Mehl

Plate II, figure 28

Palmatolepis quadrantinodosa Branson and Mehl, 1933, Missouri Univ. Studies, vol. 8, no. 3, p. 235, pl. 18, figs. 3, 17, 20.

Plate broad, subovate in outline, sigmoidally curved, oral surface ornamented with small to moderate-sized tubercles which tend to form rows extending perpendicular to carina; azygous node broadly conical; anterior part of carina straight, consisting of a few small nodes, posterior part curved, crested with small nodes, blade-like posteriorly.

Hypotype, Ohio State University Geological Museum, no. 18419.

Palmatolepis regularis Cooper

Plate II, figure 29

Palmatolepis regularis Cooper, 1931, Jour. Paleontology, vol. 5, p. 242, pl. 28, fig. 36.

Plate sigmoidal in outline, without lobes, pointed at both ends, oral surface minutely granulose, aboral surface almost smooth but showing very faint concentric lines, keel low and sharp; carina sigmoidally curved, crest nodose, probably high and blade-like posteriorly.

Hypotype, Ohio State University Geological Museum, no. 18420.

Palmatolepis subperlobata Branson and Mehl

Plate II, figure 27

Palmatolepis subperlobata Branson and Mehl, 1933, Missouri Univ. Studies, vol. 8, no. 3, p. 235, pl. 18, figs. 11, 12.

Plate thin, broad, with wide lateral lobe, oral surface minutely granulose, aboral surface marked with fine concentric lines and small median keel; azygous node rounded, dome-like; carina back of azygous node is sharp, curved, with a faintly nodose crest, becoming high and blade-like posteriorly; the carina anterior to azygous node is low and faintly nodose; in some specimens a faint ridge branches from the carina and extends through the lateral lobe.

Hypotype, Ohio State University Geological Museum, no. 18418.

Genus **Polygnathus** Hinde, 1879

Polygnathus nodocostata Branson and Mehl

Plate II, figure 22

Polygnathus nodocostata Branson and Mehl, 1933, Missouri Univ. Studies, vol. 8, no. 3, p. 246, pl. 20, figs. 9–13, pl. 21, fig. 15.

Plate subovate, slightly convex on oral side, marked with two or three rows of coalesced tubercles on each side of carina; carina prominent, extending full length of blade, slightly curved, marked with tiny nodes along crest; blade short, thick at base but with sharp crest.

Hypotype, Ohio State University Geological Museum, no. 18413.

Polygnathus pennatuloidea Holmes

Plate II, figure 21

Polygnathus pennatuloidea Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 32, pl. 11, fig. 14.

Plate subovate, oral surface convex, ornamented with irregularly arranged tubercles and a prominent, wide-based carina, crested with a series of nodes and extending the full length of the plate; blade long and thin. One specimen only, an impression of the oral surface of the plate, has been recognized.

Hypotype, Ohio State University Geological Museum, no. 18414.

Polygnathus sublatus Ulrich and Bassler

Plate II, figure 23

Polygnathus sublatus Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc., vol. 68, art. 12, p. 47, pl. 8, fig. 2.

Plate ovate and somewhat curved, oral surface slightly convex, ornamented with rows of small tubercles arranged in radial rows; carina broad, low, faintly nodose; plate thin, probably long.

The species is represented by a single impression of the oral surface of the plate.

Hypotype, Ohio State University Geological Museum, no. 18415.

Polygnathus sp.

Plate II, figure 20

Plate ovate, slightly curved, somewhat constricted on one side near anterior end; aboral surface marked with fine concentric lines, a sharp median keel, and an escutcheon; oral surface not known; blade long, thin.

Represented by an impression of the aboral side of the plate and therefore lacking sufficient evidence for specific designation.

Figured specimen, Ohio State University Geological Museum, no. 18412.

Genus **Prioniodina** Ulrich and Bassler, 1926

Prioniodina separans Holmes

Plate I, figure 27

Prioniodina separans Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 27, pl. 9, figs. 16, 17.

Bar long, rounded, moderately arched, posterior part slightly offset laterally at cusp; cusp long, slender, very slightly curved, inclined posteriorly; denticles long, thin, almost straight, widely separated, anterior denticles larger than posterior ones.

Hypotype, Ohio State University Geological Museum, no. 18392.

Genus **Prioniodus** Pander, 1856

Prioniodus alatoides Holmes

Plate I, figures 5, 7

Prioniodus alatoides Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 24, pl. 9, fig. 3.

Bar straight, narrow, of nearly uniform proportions throughout its length; cusp long, slim, slightly tapered, inclined forward; anticusp short, triangular in outline, distinctly flattened posteriorly, anterior edge essentially in line with anterior edge of cusp; denticles large, long, and tapering, discrete, inclined slightly forward, numbering ten to fourteen. The presence of minute suppressed bar denticles is indicated in some clear impressions as represented in figure 7, Plate I. In the anterior margin of the anticusp small germ denticles are faintly visible in well preserved specimens. They are distinct in weathered specimens and in some impressions.

Hypotypes, Ohio State University Geological Museum, nos. 18369, 18371.

Prioniodus alatoideus Cooper

Plate I, figures 4, 6

Prioniodus alatoideus Cooper, 1931, Jour. Paleontology, vol. 5, p. 232, pl. 28, fig. 1.

Tooth small with thin, flat, straight bar; cusp long, slim, slightly tapered, inclined forward; anticusp short, subtriangular in outline, flattened toward both edges; denticles numerous, long,

slender, inserted and confluent nearly to tips, slightly inclined forward. Minute germ denticles are inserted in anterior edge of anticusp.

The specimens from the Ohio shale compare favorably in size with the holotype and with Cooper's and Sloss's hypotypes (1943, pl. 29, figs. 6, 7, 11), but they are less than half as large as the hypotypes described by Huddle (1934, p. 37, pl. 1, figs. 4, 5) and by Cooper (1939, p. 404, pl. 45, fig. 62; pl. 46, fig. 19). The short, thick bar represented in the fossil impression illustrated in figure 4 is considered a variation within the species. (Cf. Cooper and Sloss, 1943, pl. 29, fig. 6.)

The species is distinguished from *P. alatoides* Holmes (1928, p. 24, pl. 9, fig. 3) on the basis of its numerous, fine, inserted and confluent denticles.

Hypotypes, Ohio State University Geological Museum, nos. 18368, 18370.

Prioniodus alatus Hinde

Plate I, figure 9

Prioniodus ? alatus Hinde, 1879, Geol. Soc. London, Quart. Jour., vol. 35, p. 361, pl. 16, fig. 5.

Bar straight, thick, high, aboral edge sharp; cusp massive, broad, compressed, sharp-edged, inclined forward, projected below bar to form a rather short, triangular anticusp, anterior edge of cusp and anticusp forming a straight line; denticles closely appressed, deeply inserted, free only at tips, regularly decreasing in size posteriorly, a few minute suppressed germ denticles visible between embedded portions of developed denticles.

Hypotype, Ohio State University Geological Museum, no. 18373.

Prioniodus cultratus Ulrich and Bassler

Plate I, figure 8

Prioniodus cultratus Ulrich and Bassler, 1926, U. S. Nat. Mus. Proc. vol. 68, art. 12, p. 9, pl. 9, fig. 7.

Bar short, straight, and rather thin; cusp vertical, long, broad, compressed, sharp-edged; anterior edge straight and posterior edge curved giving the effect of a slight forward inclination; anticusp very small, representing merely an anterior expansion of the bar to meet the slight aboral projection of the anterior edge of the cusp; denticles long, straight, slightly inclined posteriorly, ten or twelve in number, inserted, basal portions closely appressed but upper two-thirds discrete, a few suppressed denticles between developed ones.

The large, broad, compressed, vertical cusp is distinctive of this species. The specimens in the collection studied resemble the specimen figured by Holmes (1928, p. 24, pl. 9, fig. 4) but differ from those figured by Cooper (1931a, p. 146, pl. 20, fig. 2; 1935, pl. 27, fig. 4) in that his fossils show a thin, recurved cusp and curved denticles quite widely separated on the bar.

Hypotype, Ohio State University Geological Museum, no. 18372.

Genus **Spathognathodus** Branson and Mehl, 1941

Genus *Spathodus* Branson and Mehl, 1933, Missouri Univ. Studies, vol. 8, no. 1, p. 46.
Genus *Spathognathodus* Branson and Mehl, 1941, Jour. Paleontology, vol. 15, p. 98.

Spathognathodus subrectus (Holmes)

Plate II, figure 19

Panderodella subrecta Holmes, 1928, U. S. Nat. Mus. Proc., vol. 72, art. 5, p. 31, pl. 10, fig. 15.
Spathodus subrectus (Holmes) Huddle, 1934, Bull. Am. Paleontology, vol. 21, no. 72, p. 91, pl. 7, fig. 17.

Bar high, nearly straight, aboral expansion situated near anterior end; denticles short, confluent except at tips, subequal in size, slightly longer at posterior end of bar than at anterior end.

Hypotype, Ohio State University Geological Museum, no. 18410.

Genus **Subbryantodus** Branson and Mehl, 1933

Subbryantodus radians Branson and Mehl

Plate II, figure 13

Subbryantodus radians Branson and Mehl, 1938, Missouri Univ. Studies, vol. 13, no. 4, p. 141, pl. 34, figs. 22, 23.

Bar short, high, rather thick, moderately arched, aboral edge sharp except for small expansion beneath cusp; cusp short, very wide at base and sharply pointed, thus having a triangular outline; it is inclined and tends to suppress the adjacent posterior denticles; denticles close-set but not confluent, inclined, inserted, posterior ones about half as large as anterior ones, four to six on each side of cusp.

This form is much smaller than the holotype, but the proportionately large cusp, the few denticles, and small aboral expansion below cusp relate it to the species.

Hypotype, Ohio State University Geological Museum, no. 18403.

Subbryantodus sp.

Plate II, figure 18

Tooth small, bar strongly arched, rather high, anterior part thin, straight-sided, laterally straight, posterior part somewhat rounded and curved laterally, apical pit and aboral grooves distinct; apical denticle slightly inclined, short, broad, not sharply distinguished from other large denticles; denticles short, broad, closely appressed, some overlapping, deeply inserted, with minute germ denticles visible deep within bar, small denticles alternating with the large ones on anterior part of bar.

The single specimen of the species in this collection resembles the paratype of *Subbryantodus radians* Branson and Mehl (1938, p. 141, pl. 34, fig. 22), but it lacks the prominent apical denticle characteristic of the species. Additional material is necessary before specific assignment can be made.

Figured specimen, Ohio State University Geological Museum, no. 18408.

Genus **Synprioniodina** Ulrich and Bassler, 1926

Synprioniodina sp.

Plate I, figure 13

Bar short, slightly arched; cusp rather small, flattened, wide at base but tapering rapidly to a sharp point, inclined strongly forward; downward projection of bar (anticusp?) long, broad at base and tapering to a point resulting in a triangular outline; bar denticles fifteen or twenty in number, of medium length, slender, closely set, sharply pointed, curved anteriorly and decreasing in size posteriorly; two or more large denticles closely set in front of cusp, smaller denticles along anterior edge of downward projection, decreasing in size downward, inclined strongly upward.

The few specimens of the species in this collection are impressions, and these indicate distinct features which suggest an undescribed species. However, it is thought best to defer definite assignment until more material can be obtained for study purposes.

Figured specimen, Ohio State University Geological Museum, no. 18376.

DERMAL PLATES

Plate II, figures 24, 30

Black, lustrous plates, rather thin, rhomboid in outline, two margins marked by fine striae which produce a feather-edge effect, surfaces containing small depressions which are elongate longitudinally and irregularly spaced. The plates are of various sizes and dimensions ranging in length from 1.5 to 2.5 mm.

These plates are presumably parts of the protective armour of some type of fish or fish-like animal, but at the present time it is impossible to tie them up with anything definite. Their association with conodonts suggests a morphological relationship.

Figured specimens, Ohio State University Geological Museum, no. 18421.

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